MACHINERY'S DATA SHEETS

REVISED AND RE-ARRANGED IN LIBRARY FORM

No. 5

Spur Gearing

PRICE 25 CENTS

CONTENTS

The Industrial Press, 49-55 Lafayette Street, New York
Publishers of MACHINERY

MACHINERY'S DATA SHEET SERIES

COMPILED FROM MACHINERY'S MONTHLY DATA SHEETS AND ARRANGED WITH EXPLANATORY MATTER

No. 5

Spur Gearing

CONTENTS

In the following pages are compiled a number of diagrams and concise tables relating to the dimensions and strength of spur gearing, carefully selected from MACHINERY'S monthly Data Sheets, issued as supplements to the Engineering and Railway editions of MACHINERY since September, 1898. A number of additional tables and diagrams also are included which are published here for the first time.

In order to enhance the value of the tables and diagrams, brief explanatory notes have been provided. At the end of these notes a list of references is given to articles which have appeared in MACHINERY, and to matter published in MACHINERY'S Reference Series and Jig Sheets, giving additional information on the subject. These references will be of considerable value to readers who wish to make a more thorough study of the subject. In a note at the foot of each table reference is made to the page on which the explanatory note relating to the table appears.

SPUR GEARING

Diametral and Circular Pitch

A table for converting diametral pitch into circular pitch, and *vice versa*, is given on page 5. From this table the circular pitch can be found at a glance when the diametral pitch is given, and the diametral pitch, if the circular pitch is known. On the same page is also given a table showing the depth of space and thickness of tooth in spur gears cut with the Brown & Sharpe Mfg. Co's cutters, for 14½-degree standard involute teeth. In this latter table the "Pitch of Cutter" column gives, of course, the diametral pitch of the gear to be cut.

Spur Gear Dimensions

On page 6 is given a chart for the dimensions of spur gears. The first column headed "No." simply gives the number of the rule or formula, and is intended for quick reference to any particular rule. The meaning of the letters in the formulas can easily be ascertained by comparing them with the rules written out in words. [MACHINERY's Reference Series No. 15, Spur Gearing, Chapter II; MACHINERY's Jig Sheet No. 4B, Dimensions of Spur Gears.]

Tables of Pitch Diameters

On pages 8 to 11, inclusive, are given the pitch diameters of gears when the number of teeth and the diametral pitch are known. If the pitch diameter of a gear is to be found, locate the number of teeth in the column to the left and the diametral pitch at the top of the table. Then read off the corresponding pitch diameter in the column headed by the given diametral pitch and opposite the number of teeth. For example, if the number of teeth is 21 and the diametral pitch 2¾, then the pitch diameter is read off on page 8 as 7.63 inches.

It is evident that if the number of teeth and the pitch diameter are known the diametral pitch can be found, and if the diametral pitch and the pitch diameter are known the number of teeth can be found. If, for example, it is known that a gear having a pitch diameter of 28 inches has 77 teeth, then by locating 28 in the body of the table in line with 77 in the column under the number of teeth, the diametral pitch is found on page 9 to be 2¾. In the same way, if the diametral pitch is known to be 2½ and the pitch diameter is 26, then the number of teeth, as found on page 9, is 65.

If the circular pitch and the number of teeth are given, the pitch diameter is found on pages 12 to 15, inclusive. The number of teeth is given in the left-hand column and the circular pitch in inches at the top of the table. The method of using these tables is exactly the same as for the tables for pitch diameters when the diametral pitch is given. [MACHINERY's Reference Series No. 15, Spur Gearing, Chapter II.]

Grant's Odontograph

On pages 16 and 17 are given directions for using Grant's odontograph tables. The diagrams and tables given provide simple means for laying out accurately shaped gear teeth by means of circular arcs. These circular arcs approximate the exact tooth curves very closely. The directions given on pages 16 and 17 include the cycloidal and the 15-degree involute system.

Rolling Mill Gears

On page 18 is given a table for laying out special 22½-degree involute gears for rolling mills. All the necessary dimensions are given and the remarks in the lower part of the table give additional information relating to the calculation of the strength of the gears, and their general design. It will be seen that the shape of these teeth varies somewhat from the standard shape, and that very liberal fillets are provided at the root of the teeth in order to prevent breakage on account of sharp corners at these points.

Strength of Spur Gears

On page 19, a table of constants and a series of rules and formulas are given by means of which the strength of spur gears can be quickly calculated. The formulas given are based on the use of the diametral pitch, and the constants Y given in the table for use in the formulas are valid only when the diametral pitch is used. If the circular pitch is given, it should be transformed to diametral pitch either by dividing 3.1416 by the circular pitch, or by finding the corresponding diametral pitch directly from the table given on page 5. By means of the formulas given, the horse-power which can be transmitted by a gear of given pitch diameter, and of a given diametral pitch, running at a given number of revolutions per minute, can be found by using Formulas (1) to (4) in the order given. The only factor that is to be assumed in these calculations is the allowable static unit stress for the material in the gear. For ordinary workmanship this factor may be assumed to be 6,000 pounds per square inch for cast iron, 9,000 for phosphor-bronze, and 15,000 for steel. For high-grade workmanship these factors may be increased to 8,000, 12,000 and 20,000, respectively. The formulas, as given, are based on the well-known formula proposed by Mr. Wilfred Lewis, and first described by him in a paper read before the Engineers' Club of Philadelphia.

As an example, assume that it is required to find the horse-power which it is permissible to transmit by a spur gear having 15-inch pitch diameter, 4 diametral pitch, making 100 revolutions per minute, and having a width of face of 1½ inch, if made according to the 14½-degree involute system. The gear is made of steel and the allowable static unit stress for the material may, therefore, be assumed to be 15,000 pounds per square inch. We now first insert the values of the revolutions per minute and the pitch diameter in Formula (1), and thus find the velocity in feet per minute at the pitch diameter. This velocity, as found in Formula (1), together with the allowable static unit stress, is then inserted in Formula (2), and the allowable unit stress at the given velocity is then found. This unit stress is now inserted in Formula (3), together with the width of face, the outline factor Y (which is found from the table to be 0.358 for 60 teeth), and the diametral pitch, and in this way we find the maximum safe tangential load W. Finally, by inserting the value of W just found, and the value of V found from Formula (1), in Formula (4), we determine the maximum safe horse-power which can be transmitted by the gear. The numerical calculations are easily carried out, and it is not necessary to repeat them here. [MACHINERY'S Reference Series No. 15, Second Edition, Chapter IV.]

Diagrams for the Strength of Spur Gears

On page 20 is given a diagram for the strength of 15-degree involute and cycloidal spur gears based on the Lewis formula, with the strength factors slightly modified. This chart can be used either for finding the strength of a given gear or for finding the proper pitch and width of face of a gear to carry a given load.

(Continued on page 7.)

DIAMETRAL AND CIRCULAR PITCH, DEPTH OF SPACE AND THICKNESS OF TOOTH

Table of Diametral and Circular Pitch.

Diametral into Circular Pitch				Circular into Diametral Pitch			
Diametral Pitch	Circular Pitch	Diametral Pitch	Circular Pitch	Circular Pitch	Diametral Pitch	Circular Pitch	Diametral Pitch
1¼	2.513"	11	0.286"	2"	1.571	⅞"	3.590
1½	2.094	12	0.262	1⅞	1.676	13/16	3.867
1¾	1.795	14	0.224	1¾	1.795	¾	4.189
2	1.571	16	0.196	1⅝	1.933	11/16	4.570
2¼	1.396	18	0.175	1½	2.094	⅝	5.027
2½	1.257	20	0.157	1 7/16	2.185	9/16	5.585
2¾	1.142	22	0.143	1⅜	2.285	½	6.283
3	1.047	24	0.131	1 5/16	2.394	7/16	7.181
3½	0.898	26	0.121	1¼	2.513	⅜	8.378
4	0.785	28	0.112	1 3/16	2.646	5/16	10.053
5	0.628	30	0.105	1⅛	2.793	¼	12.566
6	0.524	32	0.098	1 1/16	2.957	3/16	16.755
7	0.449	36	0.087	1	3.142	⅛	25.133
8	0.393	40	0.079	15/16	3.351	1/16	50.266
9	0.349	48	0.065				
10	0.314						

Table Showing Depth of Space and Thickness of Tooth in Spur Gears Cut with B. & S. Mfg. Co.'s Cutters.

Pitch of Cutter	Depth to be Cut in Gear	Thickness of Tooth at Pitch Line	Pitch of Cutter	Depth to be Cut in Gear	Thickness of Tooth at Pitch Line
1¼	1.726"	1.257"	11	0.196"	0.143"
1½	1.438	1.047	12	0.180	0.131
1¾	1.233	0.898	14	0.154	0.112
2	1.078	0.785	16	0.135	0.098
2¼	0.958	0.697	18	0.120	0.087
2½	0.863	0.628	20	0.108	0.079
2¾	0.784	0.570	22	0.098	0.071
3	0.719	0.523	24	0.090	0.065
3½	0.616	0.448	26	0.083	0.060
4	0.539	0.393	28	0.077	0.056
5	0.431	0.314	30	0.072	0.052
6	0.359	0.262	32	0.067	0.049
7	0.308	0.224	36	0.060	0.044
8	0.270	0.196	40	0.054	0.039
9	0.240	0.175	48	0.045	0.033
10	0.216	0.157			

Explanatory note: Page 3.

CHART FOR DIMENSIONS OF SPUR GEARS

No.	To Find	Rule	Formula
1	Diametral Pitch	Divide 3.1416 by circular pitch	$P = \frac{3.1416}{P'}$
2	Circular Pitch	Divide 3.1416 by diametral pitch	$P' = \frac{3.1416}{P}$
3	Pitch Diameter	Divide number of teeth by diametral pitch	$D = \frac{N}{P}$
4	Pitch Diameter	Multiply number of teeth by circular pitch and divide the product by 3.1416	$D = \frac{NP'}{3.1416}$
5	Center Distance	Add the number of teeth in both gears and divide the sum by two times the diametral pitch	$C = \frac{N_g + N_p}{2P}$
6	Center Distance	Multiply the sum of the number of teeth in both gears by circular pitch and divide the product by 6.2832	$C = \frac{(N_g + N_p)P'}{6.2832}$
7	Addendum	Divide 1 by diametral pitch	$S = \frac{1}{P}$
8	Addendum	Divide circular pitch by 3.1416	$S = \frac{P'}{3.1416}$
9	Clearance	Divide 0.157 by diametral pitch	$F = \frac{0.157}{P}$
10	Clearance	Divide circular pitch by 20	$F = \frac{P'}{20}$
11	Whole Depth of Tooth	Divide 2.157 by diametral pitch	$W = \frac{2.157}{P}$
12	Whole Depth of Tooth	Multiply 0.6866 by circular pitch	$W = 0.6866 P'$
13	Thickness of Tooth	Divide 1.5708 by diametral pitch	$T = \frac{1.5708}{P}$
14	Thickness of Tooth	Divide circular pitch by 2	$T = \frac{P'}{2}$
15	Outside Diameter	Add 2 to the number of teeth and divide the sum by diametral pitch	$O = \frac{N+2}{P}$
16	Outside Diameter	Multiply the sum of the number of teeth plus 2 by circular pitch and divide the product by 3.1416	$O = \frac{(N+2)P'}{3.1416}$
17	Diametral Pitch	Divide number of teeth by pitch diameter	$P = \frac{N}{D}$
18	Circular Pitch	Multiply pitch diameter by 3.1416 and divide by number of teeth	$P = \frac{3.1416 D}{N}$
19	Pitch Diameter	Subtract two times the addendum from outside diameter	$D = O - 2S$
20	Number of Teeth	Multiply pitch diameter by diametral pitch	$N = P \times D$
21	Number of Teeth	Multiply pitch diameter by 3.1416 and divide the product by circular pitch	$N = \frac{3.1416 D}{P'}$
22	Outside Diameter	Add two times the addendum to the pitch diameter	$O = D + 2S$
23	Length of Rack	Multiply number of teeth in rack by 3.1416 and divide by diametral pitch	$L = \frac{3.1416 N}{P}$
24	Length of Rack	Multiply the number of teeth in the rack by circular pitch	$L = NP'$

Explanatory note: Page 3.

To find the strength of a given gear, follow the vertical line representing the number of teeth to its intersection with the oblique line for the proper speed, and from this point follow the horizontal line to the left and read off the working load for one inch pitch and one inch face. Multiply this by the product of the face and the circular pitch, and the result is the working load in pounds for the given gear, if the workmanship is good and the service not severe. If the contrary is the case, use the working loads in the column on the right.

To find the proper pitch and width of face of a gear to carry a given load, proceed in the same manner as in the case above, going to the left or right, according to the workmanship and service, and divide the given load by the working load for one inch pitch and one inch face, as obtained from the chart. The quotient obtained equals the product of the circular pitch and width of face of the required gear. When using diametral pitch, reduce it to circular pitch by the aid of the table given at the top of the chart or by the table given on page 5.

Example: What would be the pitch and face of a 15-tooth cast-iron pinion running at a velocity of 1,000 feet per minute and transmitting a working load of 650 pounds at the pitch line? By the chart we find in the column to the left that the working load for one inch pitch and one inch face, with the given conditions, is 225 pounds; then $650 \div 225 = 2.89 =$ product of pitch and face of the required gear. One inch pitch and three inches face would fulfill the conditions with a margin of safety. [Machinery, December, 1906, Strength of Gears.]

On pages 21 to 23, inclusive, are given additional diagrams for determining the strength of spur gears without calculations. The explanatory notes and the examples given on the diagrams illustrate their use. The diagram on page 21 gives the number of pounds pressure at the pitch line, and this value is used for finding the proportions of the gear teeth in the diagrams on pages 22 and 23, the former being for 20-degree involute cut teeth and the latter for cycloidal cut teeth. By means of these diagrams, the circular pitch and width of face of the gear is found when the horse-power to be transmitted, the number of revolutions per minute, and the pitch diameter of the gear are given.

Tables of Relation between Velocity, Load and Diametral Pitch

On pages 24 and 25 convenient tables are given for determining the diametral pitches for 15-degree involute and cycloidal cast-iron gear teeth when the load in pounds per inch width of face, the circumferential velocity, and the number of teeth are given. The speed or circumferential velocity of the teeth, as indicated in the headings of the various tables, is first located; then the load in pounds per inch width of face is found in the column to the left, and the number of teeth located at the top of the tables. The diametral pitch is then obtained from the figures in the body of the tables, opposite the load in pounds and in the column under the teeth. For example: Assume that it is required to find the diametral pitch of the teeth in a pinion having 15 teeth, running at a speed of 150 feet per minute, and subjected to a load of 500 pounds per inch width of face at the pitch line. As the speed of the teeth is between 100 and 200 feet per minute, the answer is found in the lower table on page 24, opposite 500 in the left-hand column, and beneath the heading "14—16 teeth" at the top of the column. The required diametral pitch of the teeth then is 2¾. If the gear is 3 inches wide and subjected at the pitch line to a load of 600 pounds, the load per inch width of face is, of course, 200

(Continued on page 32.)

PITCH DIAMETERS FOR DIAMETRAL PITCH GEARS—I

Number of Teeth	Diametral Pitch.						
	2 P	2¼ P	2½ P	2¾ P	3 P	4 P	5 P
10	5.00	4.44	4.00	3.63	3.33	2.50	2.00
11	5.50	4.88	4.40	4.00	3.66	2.75	2.20
12	6.00	5.33	4.80	4.36	4.00	3.00	2.40
13	6.50	5.77	5.20	4.72	4.33	3.25	2.60
14	7.00	6.22	5.60	5.09	4.66	3.50	2.80
15	7.50	6.66	6.00	5.45	5.00	3.75	3.00
16	8.00	7.11	6.40	5.81	5.33	4.00	3.20
17	8.50	7.55	6.80	6.18	5.66	4.25	3.40
18	9.00	8.00	7.20	6.54	6.00	4.50	3.60
19	9.50	8.44	7.60	6.91	6.33	4.75	3.80
20	10.00	8.88	8.00	7.27	6.66	5.00	4.00
21	10.50	9.33	8.40	7.63	7.00	5.25	4.20
22	11.00	9.77	8.80	8.00	7.33	5.50	4.40
23	11.50	10.22	9.20	8.36	7.66	5.75	4.60
24	12.00	10.66	9.60	8.72	8.00	6.00	4.80
25	12.50	11.11	10.00	9.09	8.33	6.25	5.00
26	13.00	11.55	10.40	9.45	8.66	6.50	5.20
27	13.50	12.00	10.80	9.81	9.00	6.75	5.40
28	14.00	12.44	11.20	10.18	9.33	7.00	5.60
29	14.50	12.88	11.60	10.54	9.66	7.25	5.80
30	15.00	13.33	12.00	10.91	10.00	7.50	6.00
31	15.50	13.77	12.40	11.27	10.33	7.75	6.20
32	16.00	14.22	12.80	11.63	10.66	8.00	6.40
33	16.50	14.66	13.20	12.00	11.00	8.25	6.60
34	17.00	15.11	13.60	12.36	11.33	8.50	6.80
35	17.50	15.55	14.00	12.72	11.66	8.75	7.00
36	18.00	16.00	14.40	13.09	12.00	9.00	7.20
37	18.50	16.44	14.80	13.45	12.33	9.25	7.40
38	19.00	16.88	15.20	13.81	12.66	9.50	7.60
39	19.50	17.33	15.60	14.18	13.00	9.75	7.80
40	20.00	17.77	16.00	14.54	13.33	10.00	8.00
41	20.50	18.22	16.40	14.91	13.66	10.25	8.20
42	21.00	18.66	16.80	15.27	14.00	10.50	8.40
43	21.50	19.11	17.20	15.63	14.33	10.75	8.60
44	22.00	19.55	17.60	16.00	14.66	11.00	8.80
45	22.50	20.00	18.00	16.36	15.00	11.25	9.00
46	23.00	20.44	18.40	16.72	15.33	11.50	9.20
47	23.50	20.88	18.80	17.09	15.66	11.75	9.40
48	24.00	21.33	19.20	17.45	16.00	12.00	9.60
49	2450	21.77	19.60	17.81	16.33	12.25	9.80
50	25.00	22.22	20.00	18.18	16.66	12.50	10.00
51	25.50	22.66	20.40	18.54	17.00	12.75	10.20
52	26.00	23.11	20.80	18.91	17.33	13.00	10.40
53	26.50	23.55	21.20	19.27	17.66	13.25	10.60
54	27.00	24.00	21.60	19.63	18.00	13.50	10.80
55	27.50	24.44	22.00	20.00	18.33	13.75	11.00

Contributed by E. C. Sedgwick. Explanatory note: Page 3.

PITCH DIAMETERS FOR DIAMETRAL PITCH GEARS—II

Number of Teeth	Diametral Pitch. (Continued).					
	2 P	2¼ P	2½ P	2¾ P	3 P	4 P	5 P
56	28.00	24.88	22.40	20.36	18.66	14.00	11.20
57	28.50	25.33	22.80	20.72	19.00	14.25	11.40
58	29.00	25.77	23.20	21.09	19.33	14.50	11.60
59	29.50	26.22	23.60	21.45	19.66	14.75	11.80
60	30.00	26.66	24.00	21.81	20.00	15.00	12.00
61	30.50	27.11	24.40	22.18	20.33	15.25	12.20
62	31.00	27.55	24.80	22.54	20.66	15.50	12.40
63	31.50	28.00	25.20	22.91	21.00	15.75	12.60
64	32.00	28.44	25.60	23.27	21.33	16.00	12.80
65	32.50	28.88	26.00	23.63	21.66	16.25	13.00
66	33.00	29.33	26.40	24.00	22.00	16.50	13.20
67	33.50	29.77	26.80	24.36	22.33	16.75	13.40
68	34.00	30.22	27.20	24.72	22.66	17.00	13.60
69	34.50	30.66	27.60	25.09	23.00	17.25	13.80
70	35.00	31.11	28.00	25.45	23.33	17.50	14.00
71	35.50	31.55	28.40	25.81	23.66	17.75	14.20
72	36.00	32.00	28.80	26.18	24.00	18.00	14.40
73	36.50	32.44	29.20	26.54	24.33	18.25	14.60
74	37.00	32.88	29.60	26.91	24.66	18.50	14.80
75	37.50	33.33	30.00	27.27	25.00	18.75	15.00
76	38.00	33.77	30.40	27.63	25.33	19.00	15.20
77	38.50	34.22	30.80	28.00	25.66	19.25	15.40
78	39.00	34.66	31.20	28.36	26.00	19.50	15.60
79	39.50	35.11	31.60	28.72	26.33	19.75	15.80
80	40.00	35.55	32.00	29.09	26.66	20.00	16.00
81	40.50	36.00	32.40	29.45	27.00	20.25	16.20
82	41.00	36.44	32.80	29.81	27.33	20.50	16.40
83	41.50	36.88	33.20	30.18	27.66	20.75	16.60
84	42.00	37.33	33.60	30.54	28.00	21.00	16.80
85	42.50	37.77	34.00	30.91	28.33	21.25	17.00
86	43.00	38.22	34.40	31.27	28.66	21.50	17.20
87	43.50	38.66	34.80	31.63	29.00	21.75	17.40
88	44.00	39.11	35.20	32.00	29.33	22.00	17.60
89	44.50	39.55	35.60	32.36	29.66	22.25	17.80
90	45.00	40.00	36.00	32.72	30.00	22.50	18.00
91	45.50	41.44	36.40	33.09	30.33	22.75	18.20
92	46.00	41.88	36.80	33.45	30.66	23.00	18.40
93	46.50	42.33	37.20	33.81	31.00	23.25	18.60
94	47.00	42.77	37.60	34.18	31.33	23.50	18.80
95	47.50	43.22	38.00	34.54	31.66	23.75	19.00
96	48.00	43.66	38.40	34.91	32.00	24.00	19.20
97	48.50	44.11	38.80	35.27	32.33	24.25	19.40
98	49.00	44.55	39.20	35.63	32.66	24.50	19.60
99	49.50	45.00	39.60	36.00	33.00	24.75	19.80
100	50.00	45.44	40.00	36.36	33.33	25.00	20.00

Contributed by E. C. Sedgwick. Explanatory note: Page 3.

PITCH DIAMETERS FOR DIAMETRAL PITCH GEARS—III

Number of Teeth	Diametral Pitch. (Continued).						
	6 P	8 P	10 P	12 P	14 P	16 P	20 P
10	1.66	1.25	1.00	0.83	0.71	0.62	0.50
11	1.83	1.37	1.10	0.91	0.78	0.68	0.55
12	2.00	1.50	1.20	1.00	0.85	0.75	0.60
13	2.16	1.62	1.30	1.08	0.92	0.81	0.65
14	2.33	1.75	1.40	1.16	1.00	0.87	0.70
15	2.50	1.87	1.50	1.25	1.07	0.93	0.75
16	2.66	2.00	1.60	1.33	1.14	1.00	0.80
17	2.83	2.12	1.70	1.41	1.21	1.06	0.85
18	3.00	2.25	1.80	1.50	1.28	1.12	0.90
19	3.16	2.37	1.90	1.58	1.35	1.18	0.95
20	3.33	2.50	2.00	1.66	1.42	1.25	1.00
21	3.50	2.62	2.10	1.75	1.50	1.31	1.05
22	3.66	2.75	2.20	1.83	1.57	1.37	1.10
23	3.83	2.87	2.30	1.91	1.64	1.43	1.15
24	4.00	3.00	2.40	2.00	1.71	1.50	1.20
25	4.16	3.12	2.50	2.08	1.78	1.56	1.25
26	4.33	3.25	2.60	2.17	1.85	1.62	1.30
27	4.50	3.37	2.70	2.25	1.92	1.68	1.35
28	4.66	3.50	2.80	2.33	2.00	1.75	1.40
29	4.83	3.62	2.90	2.41	2.07	1.81	1.45
30	5.00	3.75	3.00	2.50	2.14	1.87	1.50
31	5.16	3.87	3.10	2.58	2.21	1.93	1.55
32	5.33	4.00	3.20	2.66	2.28	2.00	1.60
33	5.50	4.12	3.30	2.75	2.35	2.06	1.65
34	5.66	4.25	3.40	2.83	2.42	2.12	1.70
35	5.83	4.37	3.50	2.91	2.50	2.18	1.75
36	6.00	4.50	3.60	3.00	2.57	2.25	1.80
37	6.16	4.62	3.70	3.08	2.64	2.31	1.85
38	6.33	4.75	3.80	3.17	2.71	2.37	1.90
39	6.50	4.87	3.90	3.25	2.78	2.43	1.95
40	6.66	5.00	4.00	3.33	2.85	2.50	2.00
41	6.83	5.12	4.10	3.41	2.92	2.56	2.05
42	7.00	5.25	4.20	3.50	3.00	2.62	2.10
43	7.16	5.37	4.30	3.58	3.07	2.68	2.15
44	7.33	5.50	4.40	3.66	3.14	2.75	2.20
45	7.50	5.62	4.50	3.75	3.21	2.81	2.25
46	7.66	5.75	4.60	3.83	3.28	2.87	2.30
47	7.83	5.87	4.70	3.91	3.35	2.93	2.35
48	8.00	6.00	4.80	4.00	3.42	3.00	2.40
49	8.16	6.12	4.90	4.08	3.50	3.06	2.45
50	8.33	6.25	5.00	4.17	3.57	3.12	2.50
51	8.50	6.37	5.10	4.25	3.64	3.18	2.55
52	8.66	6.50	5.20	4.33	3.71	3.25	2.60
53	8.83	6.62	5.30	4.41	3.78	3.31	2.65
54	9.00	6.75	5.40	4.50	3.85	3.37	2.70
55	9.16	6.87	5.50	4.58	3.92	3.43	2.75

Contributed by E. C. Sedgwick. Explanatory note: Page 3.

PITCH DIAMETERS FOR DIAMETRAL PITCH GEARS—IV.

Number of Teeth	Diametral Pitch. (Continued).						
	6 P	8 P	10 P	12 P	14 P	16 P	20 P
56	9.33	7.00	5.60	4.66	4.00	3.50	2.80
57	9.50	7.12	5.70	4.75	4.07	3.56	2.85
58	9.66	7.25	5.80	4.83	4.14	3.62	2.90
59	9.83	7.37	5.90	4.91	4.21	3.68	2.95
60	10.00	7.50	6.00	5.00	4.28	3.75	3.00
61	10.16	7.62	6.10	5.08	4.35	3.81	3.05
62	10.33	7.75	6.20	5.17	4.42	3.87	3.10
63	10.50	7.87	6.30	5.25	4.50	3.93	3.15
64	10.66	8.00	6.40	5.33	4.57	4.00	3.20
65	10.83	8.12	6.50	5.41	4.64	4.06	3.25
66	11.00	8.25	6.60	5.50	4.71	4.12	3.30
67	11.16	8.37	6.70	5.58	4.78	4.18	3.35
68	11.33	8.50	6.80	5.66	4.85	4.25	3.40
69	11.50	8.62	6.90	5.75	4.92	4.31	3.45
70	11.66	8.75	7.00	5.83	5.00	4.37	3.50
71	11.83	8.87	7.10	5.91	5.07	4.43	3.55
72	12.00	9.00	7.20	6.00	5.14	4.50	3.60
73	12.16	9.12	7.30	6.08	5.21	4.56	3.65
74	12.33	9.25	7.40	6.17	5.28	4.62	3.70
75	12.50	9.37	7.50	6.25	5.35	4.68	3.75
76	12.66	9.50	7.60	6.33	5.42	4.75	3.80
77	12.83	9.62	7.70	6.41	5.50	4.81	3.85
78	13.00	9.75	7.80	6.50	5.57	4.87	3.90
79	13.16	9.87	7.90	6.58	5.64	4.93	3.95
80	13.33	10.00	8.00	6.66	5.71	5.00	4.00
81	13.50	10.12	8.10	6.75	5.78	5.06	4.05
82	13.66	10.25	8.20	6.83	5.85	5.12	4.10
83	13.83	10.37	8.30	6.91	5.92	5.18	4.15
84	14.00	10.50	8.40	7.00	6.00	5.25	4.20
85	14.16	10.62	8.50	7.08	6.07	5.31	4.25
86	14.33	10.75	8.60	7.17	6.14	5.37	4.30
87	14.50	10.87	8.70	7.25	6.21	5.43	4.35
88	14.66	11.00	8.80	7.33	6.28	5.50	4.40
89	14.83	11.12	8.90	7.41	6.35	5.56	4.45
90	15.00	11.25	9.00	7.50	6.42	5.62	4.50
91	15.16	11.37	9.10	7.58	6.50	5.68	4.55
92	15.33	11.50	9.20	7.66	6.57	5.75	4.60
93	15.50	11.62	9.30	7.75	6.64	5.81	4.65
94	15.66	11.75	9.40	7.83	6.71	5.87	4.70
95	15.83	11.87	9.50	7.91	6.78	5.93	4.75
96	16.00	12.00	9.60	8.00	6.85	6.00	4.80
97	16.16	12.12	9.70	8.08	6.92	6.06	4.85
98	16.33	12.25	9.80	8.17	7.00	6.12	4.90
99	16.50	12.37	9.90	8.25	7.07	6.18	4.95
100	16.66	12.50	10.00	8.33	7.14	6.25	5.00

Contributed by E. C. Sedgwick. Explanatory note: Page 3.

PITCH DIAMETERS FOR CIRCULAR PITCH GEARS—I

Number of Teeth	Circular Pitch in Inches.												
	1/2	5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2	1 5/8	1 3/4	1 7/8	2
12	1.91	2.39	2.86	3.34	3.82	4.30	4.77	5.25	5.73	6.20	6.68	7.16	7.64
13	2.07	2.59	3.10	3.62	4.14	4.66	5.17	5.69	6.21	6.72	7.24	7.76	8.28
14	2.23	2.78	3.34	3.90	4.46	5.01	5.57	6.13	6.68	7.24	7.80	8.35	8.91
15	2.39	2.98	3.58	4.18	4.77	5.37	5.97	6.56	7.16	7.76	8.35	8.95	9.54
16	2.55	3.18	3.82	4.46	5.09	5.73	6.36	7.00	7.64	8.27	8.91	9.55	10.18
17	2.70	3.38	4.06	4.73	5.41	6.09	6.76	7.44	8.11	8.79	9.47	10.14	10.82
18	2.86	3.58	4.30	5.01	5.73	6.45	7.16	7.88	8.59	9.31	10.03	10.74	11.46
19	3.02	3.78	4.54	5.29	6.05	6.80	7.56	8.32	9.07	9.83	10.58	11.34	12.10
20	3.18	3.98	4.77	5.57	6.37	7.16	7.96	8.75	9.55	10.34	11.14	11.93	12.73
21	3.34	4.18	5.01	5.85	6.68	7.52	8.35	9.19	10.03	10.86	11.70	12.53	13.37
22	3.50	4.38	5.25	6.13	7.00	7.88	8.75	9.63	10.50	11.38	12.25	13.13	14.00
23	3.66	4.57	5.49	6.41	7.32	8.23	9.15	10.07	10.98	11.90	12.81	13.73	14.64
24	3.82	4.77	5.73	6.68	7.64	8.59	9.55	10.50	11.46	12.41	13.37	14.32	15.27
25	3.98	4.97	5.97	6.96	7.96	8.95	9.95	10.94	11.94	12.93	13.93	14.92	15.91
26	4.14	5.17	6.21	7.24	8.28	9.31	10.34	11.38	12.41	13.45	14.48	15.52	16.55
27	4.30	5.37	6.44	7.52	8.59	9.67	10.74	11.82	12.89	13.96	15.04	16.11	17.19
28	4.46	5.57	6.68	7.80	8.91	10.03	11.14	12.25	13.36	14.48	15.60	16.71	17.82
29	4.61	5.77	6.92	8.08	9.23	10.38	11.54	12.69	13.84	15.00	16.15	17.31	18.46
30	4.77	5.97	7.16	8.35	9.54	10.74	11.94	13.13	14.32	15.52	16.70	17.90	19.10
31	4.93	6.17	7.40	8.63	9.86	11.10	12.33	13.57	14.80	16.03	17.27	18.50	19.73
32	5.09	6.36	7.64	8.91	10.18	11.46	12.73	14.00	15.27	16.55	17.82	19.10	20.37
33	5.25	6.56	7.88	9.19	10.50	11.82	13.13	14.44	15.75	17.07	18.38	19.69	21.00
34	5.41	6.76	8.11	9.47	10.82	12.17	13.53	14.88	16.23	17.59	18.94	20.29	21.64
35	5.57	6.96	8.35	9.75	11.14	12.53	13.93	15.32	16.71	18.10	19.49	20.89	22.27
36	5.73	7.16	8.59	10.03	11.46	12.89	14.32	15.76	17.19	18.61	20.05	21.48	22.91
37	5.89	7.36	8.83	10.30	11.78	13.25	14.72	16.19	17.67	19.13	20.61	22.08	23.55
38	6.05	7.56	9.07	10.58	12.10	13.61	15.12	16.63	18.14	19.66	21.77	22.68	24.19
39	6.21	7.76	9.31	10.86	12.41	13.97	15.52	17.07	18.62	20.17	21.73	23.28	24.83
40	6.37	7.96	9.55	11.14	12.73	14.32	15.92	17.51	19.10	20.69	22.28	23.87	25.46
41	6.52	8.16	9.79	11.42	13.05	14.68	16.31	17.94	19.58	21.21	22.84	24.47	26.09
42	6.68	8.35	10.03	11.70	13.37	15.04	16.71	18.38	20.05	21.72	23.39	25.07	26.74
43	6.84	8.55	10.26	11.97	13.69	15.40	17.11	18.82	20.53	22.24	23.95	25.66	27.37
44	7.00	8.75	10.50	12.25	14.00	15.76	17.50	19.26	21.01	22.76	24.51	26.26	28.01
45	7.16	8.95	10.74	12.53	14.32	16.11	17.90	19.69	21.48	23.28	25.07	26.86	28.65
46	7.32	9.15	10.98	12.81	14.64	16.47	18.30	20.13	21.96	23.79	25.62	27.45	29.28
47	7.48	9.35	11.22	13.09	14.96	16.83	18.70	20.57	22.44	24.31	26.18	28.05	29.92
48	7.64	9.55	11.46	13.37	15.27	17.19	19.10	21.00	22.92	24.82	26.74	28.64	30.55
49	7.80	9.75	11.70	13.65	15.59	17.55	19.50	21.44	23.39	25.34	27.29	29.24	31.19
50	7.96	9.95	11.94	13.93	15.91	17.90	19.89	21.88	23.87	25.86	27.85	29.85	31.83
51	8.12	10.15	12.17	14.20	16.23	18.26	20.29	22.32	24.35	26.38	28.41	30.44	32.47
52	8.28	10.34	12.41	14.48	16.55	18.64	20.69	22.76	24.82	26.90	28.97	31.04	33.10
53	8.43	10.54	12.65	14.76	16.87	18.98	21.09	23.20	25.30	27.41	29.52	31.63	33.74
54	8.59	10.74	12.89	15.04	17.19	19.34	21.49	23.63	25.78	27.93	30.08	32.23	34.38
55	8.75	10.94	13.13	15.32	17.51	19.69	21.88	24.07	26.26	28.45	30.64	32.82	35.01
56	8.91	11.14	13.37	15.60	17.82	20.05	22.28	24.51	26.74	28.96	31.19	33.42	35.65

Explanatory note: Page 3.

PITCH DIAMETERS FOR CIRCULAR PITCH GEARS—II

Number of Teeth	Circular Pitch in Inches. (Continued).												
	1/2	5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2	1 5/8	1 3/4	1 7/8	2
57	9.07	11.34	13.61	15.87	18.14	20.41	22.68	24.95	27.21	29.48	31.75	34.02	36.28
58	9.23	11.54	13.85	16.15	18.46	20.77	23.08	25.38	27.82	30.00	32.31	34.62	36.92
59	9.38	11.74	14.08	16.42	18.78	21.13	23.47	25.82	28.17	30.52	32.87	35.21	37.56
60	9.55	11.94	14.32	16.71	19.10	21.49	23.87	26.26	28.65	31.03	33.42	35.80	38.20
61	9.71	12.13	14.56	16.99	19.42	21.84	24.27	26.70	29.12	31.55	33.98	36.40	38.83
62	9.87	12.33	14.80	17.27	19.73	22.20	24.67	27.14	29.60	32.07	34.54	37.00	39.47
63	10.03	12.53	15.04	17.54	20.05	22.56	25.06	27.57	30.08	32.58	35.09	37.60	40.10
64	10.18	12.73	15.28	17.82	20.37	22.92	25.46	28.01	30.55	33.10	35.65	38.19	40.74
65	10.34	12.93	15.52	18.10	20.69	23.28	25.86	28.45	31.03	33.62	36.21	38.79	41.38
66	10.50	13.13	15.76	18.38	21.01	23.63	26.26	28.89	31.51	34.14	36.76	39.39	42.02
67	10.66	13.33	15.99	18.66	21.33	23.99	26.68	29.32	31.99	34.66	37.32	39.99	42.65
68	10.82	13.53	16.23	18.94	21.64	24.35	27.06	29.76	32.47	35.17	37.88	40.58	43.29
69	10.98	13.73	16.47	19.22	21.96	24.71	27.45	30.20	32.94	35.69	38.44	41.18	43.92
70	11.14	13.93	16.71	19.50	22.28	25.07	27.85	30.64	33.42	36.21	38.99	41.78	44.56
71	11.30	14.12	16.95	19.77	22.60	25.42	28.25	31.07	33.94	36.72	39.55	42.37	45.20
72	11.46	14.32	17.19	20.05	22.92	25.78	28.65	31.51	34.38	37.24	40.11	42.97	45.84
73	11.62	14.52	17.43	20.33	23.24	26.14	29.05	31.95	34.85	37.76	40.66	43.57	46.47
74	11.78	14.72	17.67	20.61	23.55	26.50	29.44	32.39	35.33	38.28	41.22	44.16	47.11
75	11.94	14.92	17.90	20.89	23.87	26.85	29.84	32.82	35.81	38.79	41.78	44.76	47.74
76	12.10	15.12	18.14	21.17	24.19	27.21	30.24	33.26	36.29	39.31	42.33	45.36	48.38
77	12.25	15.32	18.38	21.45	24.51	27.57	30.64	33.70	36.76	39.83	42.89	45.95	49.02
78	12.41	15.52	18.62	21.72	24.83	27.93	31.03	34.14	37.24	40.34	43.45	46.55	49.66
79	12.57	15.72	18.86	22.00	25.15	28.29	31.43	34.57	37.72	40.86	44.01	47.15	50.29
80	12.73	15.91	19.10	22.28	25.46	28.65	31.83	35.01	38.20	41.38	44.56	47.74	50.93
81	12.89	16.11	19.34	22.56	25.78	29.00	32.23	35.45	38.67	41.90	45.12	48.34	51.56
82	13.05	16.31	19.58	22.84	26.10	29.36	32.63	35.89	39.15	42.41	45.68	48.94	52.20
83	13.21	16.51	19.81	23.12	26.42	29.72	33.02	36.33	39.63	42.93	46.23	49.54	52.84
84	13.37	16.71	20.05	23.39	26.74	30.08	33.42	36.76	40.10	43.45	46.79	50.14	53.47
85	13.53	16.91	20.29	23.67	27.06	30.44	33.82	37.20	40.58	43.97	47.35	50.73	54.11
86	13.69	17.11	20.53	23.95	27.37	30.80	34.22	37.64	41.06	44.48	47.90	51.33	54.75
87	13.85	17.31	20.77	24.23	27.69	31.15	34.62	38.08	41.54	45.00	48.46	51.92	55.38
88	14.00	17.51	21.01	24.51	28.01	31.51	35.01	38.51	42.02	45.52	49.02	52.52	56.02
89	14.16	17.71	21.25	24.79	28.33	31.87	35.41	38.95	42.49	46.03	49.58	53.12	56.66
90	14.32	17.90	21.48	25.07	28.65	32.23	35.81	39.39	42.97	46.55	50.13	53.71	57.30
91	14.48	18.10	21.72	25.34	28.97	32.59	36.21	39.83	43.45	47.07	50.69	54.31	57.93
92	14.64	18.30	21.96	25.62	29.28	32.94	36.60	40.26	43.93	47.59	51.25	54.91	58.57
93	14.80	18.50	22.20	25.90	29.60	33.30	37.00	40.70	44.40	48.10	51.80	55.50	59.20
94	14.96	18.70	22.44	26.18	29.92	33.66	37.40	41.14	44.88	48.62	52.36	56.10	59.84
95	15.12	18.90	22.68	26.46	30.24	34.02	37.80	41.58	45.36	49.14	52.92	56.70	60.48
96	15.28	19.10	22.92	26.74	30.56	34.38	38.20	42.02	45.84	49.65	53.47	57.29	61.11
97	15.44	19.30	23.16	27.02	30.87	34.73	38.59	42.45	46.31	50.17	54.03	57.89	61.75
98	15.60	19.50	23.39	27.29	31.19	35.09	38.99	42.89	46.79	50.69	54.59	58.49	62.39
99	15.76	19.69	23.63	27.57	31.51	35.45	39.39	43.33	47.27	51.21	55.15	59.08	63.02
100	15.91	19.89	23.87	27.85	31.83	35.81	39.79	43.77	47.75	51.72	55.70	59.68	63.66

Explanatory note: Page 3.

PITCH DIAMETERS FOR CIRCULAR PITCH GEARS—III

Number of Teeth	Circular Pitch in Inches. (Continued).											
	$2\frac{1}{8}$	$2\frac{1}{4}$	$2\frac{3}{8}$	$2\frac{1}{2}$	$2\frac{5}{8}$	$2\frac{3}{4}$	$2\frac{7}{8}$	3	$3\frac{1}{4}$	$3\frac{1}{2}$	$3\frac{3}{4}$	4
12	8.12	8.59	9.07	9.54	10.03	10.50	10.98	11.45	12.41	13.36	14.32	15.28
13	8.79	9.31	9.83	10.34	10.86	11.38	11.90	12.41	13.45	14.48	15.52	16.56
14	9.47	10.03	10.59	11.14	11.70	12.25	12.81	13.36	14.49	15.60	16.71	17.82
15	10.15	10.74	11.35	11.93	12.53	13.13	13.73	14.32	15.52	16.71	17.90	19.08
16	10.82	11.46	12.09	12.73	13.36	14.00	14.64	15.28	16.55	17.82	19.10	20.36
17	11.50	12.17	12.85	13.53	14.20	14.88	15.55	16.23	17.58	18.94	20.29	21.64
18	12.17	12.89	13.61	14.32	15.04	15.76	16.47	17.19	18.61	20.05	21.49	22.92
19	12.85	13.61	14.36	15.12	15.88	16.63	17.39	18.14	19.65	21.17	22.68	24.19
20	13.53	14.32	15.12	15.92	16.71	17.51	18.30	19.10	20.68	22.28	23.87	25.46
21	14.20	15.04	15.87	16.71	17.55	18.38	19.22	20.05	21.72	23.39	25.07	26.74
22	14.88	15.76	16.63	17.50	18.38	19.26	20.13	21.01	22.76	24.51	26.26	28.01
23	15.56	16.47	17.39	18.30	19.22	20.13	21.05	21.96	23.79	25.62	27.45	29.28
24	16.23	17.19	18.14	19.10	20.05	21.01	21.96	22.92	24.82	26.74	28.64	30.55
25	16.91	17.90	18.90	19.89	20.89	21.88	22.88	23.87	25.86	27.85	29.84	31.82
26	17.59	18.62	19.65	20.69	21.73	22.76	23.79	24.83	26.90	28.97	31.03	33.10
27	18.26	19.34	20.41	21.48	22.56	23.63	24.71	25.78	27.93	30.08	32.23	34.38
28	18.94	20.05	21.17	22.28	23.39	24.51	25.62	26.74	28.96	31.19	33.42	35.65
29	19.61	20.77	21.93	23.07	24.23	25.38	26.54	27.69	30.00	32.30	34.61	36.91
30	20.29	21.48	22.69	23.87	25.06	26.26	27.45	28.64	31.03	33.41	35.81	38.19
31	20.96	22.20	23.43	24.66	25.90	27.14	28.37	29.60	32.07	34.53	37.00	39.46
32	21.64	22.92	24.19	25.46	26.73	28.01	29.28	30.55	33.10	35.65	38.20	40.74
33	22.32	23.63	24.94	26.25	27.57	28.88	30.20	31.50	34.14	36.76	39.39	42.01
34	23.00	24.34	25.70	27.05	28.41	29.76	31.11	32.46	35.17	37.87	40.58	43.28
35	23.67	25.06	26.46	27.85	29.24	30.64	32.02	33.42	36.20	38.99	41.77	44.55
36	24.35	25.78	27.21	28.65	30.08	31.51	32.94	34.38	37.23	40.10	42.97	45.82
37	25.03	26.50	27.97	29.44	30.92	32.39	33.86	35.33	38.27	41.22	44.17	47.10
38	25.70	27.21	28.73	30.24	31.75	33.26	34.78	36.29	39.31	42.33	45.36	48.38
39	26.38	27.93	29.48	31.03	32.59	34.13	35.69	37.24	40.34	43.45	46.55	49.66
40	27.06	28.65	30.24	31.83	33.42	35.01	36.60	38.19	41.38	44.56	47.74	50.93
41	27.73	29.36	30.99	32.62	34.26	35.89	37.51	39.15	42.41	45.67	48.94	52.19
42	28.41	30.08	31.75	33.42	35.09	36.76	38.43	40.11	43.45	46.79	50.13	53.47
43	29.09	30.80	32.50	34.21	35.93	37.64	39.35	41.06	44.49	47.90	51.32	54.73
44	29.77	31.51	33.26	35.01	36.77	38.51	40.27	42.01	45.53	49.02	52.52	56.01
45	30.44	32.23	34.02	35.81	37.60	39.39	41.18	42.97	46.56	50.13	53.71	57.29
46	31.11	32.94	34.77	36.60	38.43	40.26	42.10	43.93	47.59	51.25	54.91	58.57
47	31.79	33.66	35.53	37.40	39.27	41.14	43.01	44.88	48.62	52.36	56.10	59.84
48	32.47	34.38	36.28	38.19	40.10	42.02	43.92	45.84	49.65	53.47	57.29	61.11
49	33.14	35.09	37.04	38.99	40.94	42.89	44.84	46.79	50.69	54.59	58.49	62.39
50	33.82	35.81	37.79	39.79	41.78	43.77	45.76	47.75	51.72	55.70	59.69	63.66
51	34.49	36.52	38.55	40.58	42.61	44.64	46.67	48.70	52.76	56.82	60.88	64.93
52	35.17	37.24	39.31	41.38	43.45	45.51	47.58	49.65	53.79	57.93	62.07	66.21
53	35.85	37.96	40.07	42.18	44.38	46.39	48.50	50.61	54.83	59.04	63.26	67.48
54	36.53	38.68	40.83	42.97	45.12	47.27	49.42	51.56	55.86	60.16	64.46	68.76
55	37.20	39.39	41.58	43.76	45.95	48.14	50.33	52.52	56.90	61.28	65.65	70.03
56	37.88	40.11	42.33	44.56	46.79	49.02	51.24	53.47	57.93	62.39	66.84	71.30

Explanatory note: Page 3.

PITCH DIAMETERS FOR CIRCULAR PITCH GEARS—IV

Number of Teeth	Circular Pitch in Inches. (Continued).											
	2 1/8	2 1/4	2 3/8	2 1/2	2 5/8	2 3/4	2 7/8	3	3 1/4	3 1/2	3 3/4	4
57	38.55	40.82	43.09	45.36	47.63	49.89	52.16	54.43	58.97	63.51	68.03	72.57
58	39.23	41.54	43.85	46.15	48.46	50.77	53.08	55.38	60.00	64.61	69.23	73.85
59	39.91	42.25	44.60	46.95	49.30	51.64	53.99	56.34	61.03	65.73	70.42	75.12
60	40.58	42.97	45.36	47.74	50.13	52.52	54.91	57.30	62.07	66.84	71.62	76.39
61	41.26	43.69	46.11	48.54	50.97	53.39	55.82	58.25	63.10	67.95	72.81	77.67
62	41.93	44.40	46.87	49.34	51.80	54.27	56.74	59.20	64.14	69.07	74.00	78.94
63	42.61	45.12	47.62	50.13	52.63	55.14	57.65	60.16	65.17	70.18	75.19	80.21
64	43.29	45.84	48.38	50.93	53.47	56.02	58.57	61.12	66.21	71.30	76.39	81.48
65	43.97	46.55	49.14	51.72	54.31	56.90	59.48	62.07	67.24	72.42	77.59	82.76
66	44.64	47.27	49.89	52.52	55.15	57.77	60.40	63.02	68.28	73.53	78.78	84.03
67	45.32	47.98	50.65	53.32	55.98	58.65	61.32	63.98	69.31	74.64	79.97	85.30
68	45.99	48.70	51.41	54.11	56.82	59.52	62.23	64.94	70.35	75.75	81.17	86.58
69	46.67	49.42	52.16	54.91	57.65	60.40	63.14	65.89	71.38	76.87	82.36	87.85
70	47.35	50.13	52.92	55.70	58.49	61.27	64.06	66.84	72.41	77.98	83.55	89.12
71	48.02	50.85	53.67	56.50	59.32	62.15	64.97	67.80	73.45	79.10	84.75	90.40
72	48.70	51.56	54.43	57.30	60.16	63.02	65.89	68.76	74.48	80.21	85.94	91.67
73	49.38	52.28	55.19	58.09	61.00	63.90	66.80	69.71	75.52	81.32	87.14	92.94
74	50.05	53.00	55.94	58.89	61.83	64.77	67.72	70.66	76.55	82.44	88.33	94.32
75	50.73	53.71	56.70	59.68	62.66	65.65	68.63	71.62	77.59	83.55	89.52	95.49
76	51.41	54.43	57.45	60.48	63.50	66.52	69.55	72.57	78.62	84.66	90.72	96.77
77	52.08	55.14	58.21	61.27	64.33	67.40	70.46	73.53	79.66	85.78	91.91	98.04
78	52.76	55.86	58.96	62.07	65.17	68.28	71.38	74.48	80.69	86.89	93.10	99.31
79	53.43	56.58	59.72	62.86	66.01	69.15	72.29	75.44	81.72	88.01	94.30	100.58
80	54.11	57.29	60.48	63.66	66.89	70.03	73.21	76.39	82.76	89.12	95.49	101.86
81	54.79	58.01	61.23	64.46	67.68	70.90	74.12	77.35	83.79	90.24	96.68	103.13
82	55.46	58.73	61.88	65.25	68.51	71.78	75.04	78.30	84.83	91.35	97.88	104.40
83	56.14	59.44	62.75	66.05	69.35	72.65	75.96	79.26	85.86	92.47	99.07	105.67
84	56.81	60.16	63.50	66.84	70.18	73.52	76.87	80.21	86.90	93.58	100.26	106.94
85	57.49	60.88	64.26	67.64	71.02	74.40	77.79	81.17	87.93	94.70	101.46	108.22
86	58.17	61.59	65.01	68.44	71.86	75.28	78.70	82.12	88.96	95.81	102.65	109.50
87	58.85	62.31	65.77	69.23	72.69	76.15	79.61	83.08	90.00	96.92	103.85	110.77
88	59.52	63.02	66.53	70.03	73.53	77.03	80.53	84.03	91.03	98.04	105.04	112.04
89	60.20	63.74	67.28	70.82	74.36	77.91	81.45	84.99	92.07	99.15	106.24	113.32
90	60.88	64.46	68.04	71.62	75.20	78.78	82.36	85.94	93.10	100.26	107.43	114.59
91	61.55	65.17	68.79	72.41	76.03	79.65	83.27	86.90	94.14	101.38	108.62	115.86
92	62.23	65.89	69.55	73.21	76.87	80.53	84.19	87.85	95.17	102.49	109.81	117.14
93	62.90	66.60	70.30	74.00	77.70	81.41	85.11	88.81	96.21	103.61	111.01	118.41
94	63.58	67.32	71.06	74.80	78.54	82.28	86.02	89.76	97.24	104.72	112.20	119.68
95	64.26	68.04	71.81	75.60	79.38	83.16	86.94	90.72	98.28	105.84	113.39	120.95
96	64.93	68.75	72.57	76.39	80.21	84.03	87.85	91.67	99.31	106.95	114.59	122.22
97	65.61	69.47	73.33	77.19	81.05	84.91	88.76	92.62	100.34	108.06	115.78	123.50
98	66.29	70.19	74.08	77.98	81.88	85.78	89.68	93.58	101.38	109.18	116.98	124.78
99	66.96	70.90	74.84	78.78	82.72	86.66	90.60	94.54	102.41	110.29	118.17	126.05
100	67.64	71.62	75.59	79.57	83.55	87.53	91.51	95.49	103.45	111.40	119.36	127.32

Explanatory note: Page 3.

GRANT'S ODONTOGRAPH

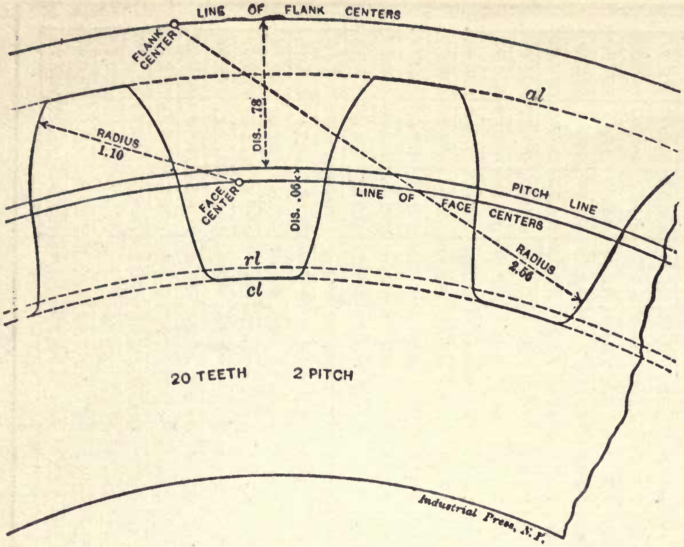


Fig. 1. Cycloidal Teeth.

Table for Cycloidal Teeth.

Number of Teeth in the Gear.		For One Diametral Pitch. For any other pitch divide by that pitch.				For One Inch Circular Pitch. For any other pitch multiply by that pitch.			
		Faces.		Flanks.		Faces.		Flanks.	
Exact.	Intervals	Rad.	Dis.	Rad.	Dis.	Rad.	Dis.	Rad.	Dis.
10	10	1.99	.02	— 8.00	4.00	.62	.01	—2.55	1.27
11	11	2.00	.04	—11.05	6.50	.63	.01	—3.34	2.07
12	12	2.01	.06	∞	∞	.64	.02	∞	∞
13½	13—14	2.04	.07	15.10	9.43	.65	.02	4.80	3.00
15½	15—16	2.10	.09	7.86	3.46	.67	.03	2.50	1.10
17½	17—18	2.14	.11	6.13	2.20	.68	.04	1.95	.70
20	19—21	2.20	.13	5.12	1.57	.70	.04	1.63	.50
23	22—24	2.26	.15	4.50	1.13	.72	.05	1.43	.36
27	25—29	2.33	.16	4.10	.96	.74	.05	1.30	.29
33	30—36	2.40	.19	3.80	.72	.76	.06	1.20	.23
42	37—48	2.48	.22	3.52	.63	.79	.07	1.12	.20
58	49—72	2.60	.25	3.33	.54	.83	.08	1.06	.17
97	73—144	2.83	.28	3.14	.44	.90	.09	1.00	.14
290	145—300	2.92	.31	3.00	.38	.93	.10	.95	.12
∞	Rack	2.96	.34	2.96	.34	.94	.11	.94	.11

CYCLOIDAL SYSTEM.

The three-point odontograph devised and calculated by Geo. B. Grant is one of the best methods for laying out accurate gear teeth or the templates for gear teeth. The odontograph gives the centers and radii for drawing circular arcs which approximate the actual tooth curves.

To apply the odontograph to any particular case of cycloidal teeth, first draw the pitch, addendum, root and clearance circles or lines, and space the pitch line for the teeth in the usual way.

Then draw the line of flank centers at the tabular distance, "dis" outside of the pitch line, and the line of face centers at the distance, "dis" inside of it. Take the face radius "rad" on the dividers, and draw in all the face curves from centers on the line of face centers; then take the flank radius "rad" and draw all the flank curves from centers on the line of flank centers.

The table gives the distances and radii if the pitch is either exactly one diametral or one inch circular, and for any other pitch multiply or divide as directed in the table. Fig. 1 shows the process applied to a practical case with the distances given in the figures. The odontograph may also be applied to laying out teeth for internal gears.

INVOLUTE SYSTEM.

To draft the tooth, lay off the pitch, addendum, root and clearance lines, and space the pitch line for the teeth, as in Fig. 2.

Draw the base line one-sixtieth of the pitch diameter inside the pitch line.

Take the tabular face radius on the dividers, after multiplying or dividing it as required by the table, and draw in all the faces from the pitch line to the addendum line from centers on the base line.

Set the dividers to the tabular flank radius, and draw in all the flanks from the pitch line to the base line.

Draw straight radial flanks from the base line to the root line, and round them into the clearance line.

Special Rule for the Involute Rack.

Draw the sides of the rack tooth as straight lines inclined to the line of centers *c O c* at an angle of fifteen degrees, best found by quartering the angle of sixty degrees.

GRANT'S ODONTOGRAPH

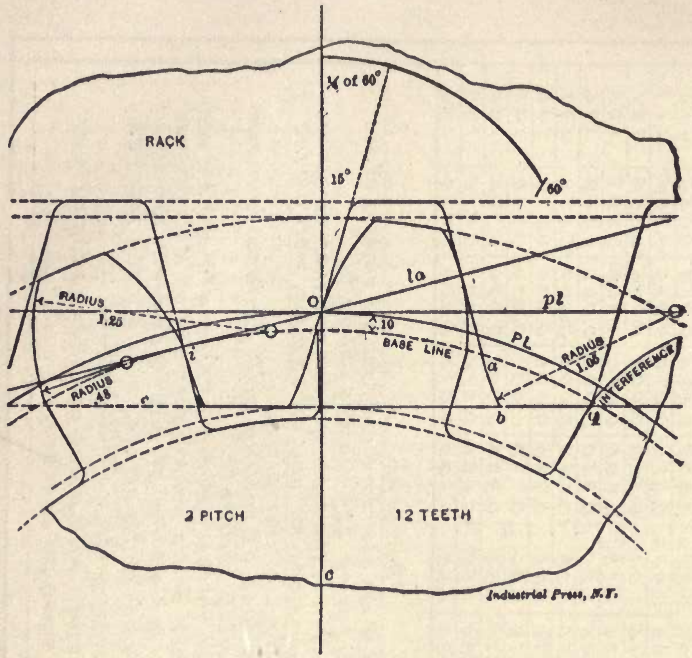


Fig. 2. Involute Teeth.

Draw the outer half *a b* of the face, one-quarter of the whole length of the tooth, from a center on the pitch line, and with a radius of

2.10 inches divided by the diametral pitch.
.67 inches multiplied by the circular pitch.

Drafting Internal Involute Gears.

When the internal gear is to be drawn, the odontograph should be used as if the gear was an ordinary external gear; but care must be taken that the tooth of the gear is cut off to avoid interference. The point of the tooth may be left off altogether or rounded over to get the appearance of a long tooth.

Table for Involute Teeth.

Teeth.	Divide by the Diametral Pitch.		Multiply by the Circular Pitch.	
	Face Radius.	Flank Radius.	Face Radius.	Flank Radius.
10	2.28	.69	.73	.22
11	2.40	.83	.76	.27
12	2.51	.96	.80	.31
13	2.62	1.09	.83	.34
14	2.72	1.22	.87	.39
15	2.82	1.34	.90	.43
16	2.92	1.46	.93	.47
17	3.02	1.58	.96	.50
18	3.12	1.69	.99	.54
19	3.22	1.79	1.03	.57
20	3.32	1.89	1.06	.60
21	3.41	1.98	1.09	.63
22	3.49	2.06	1.11	.66
23	3.57	2.15	1.13	.69
24	3.64	2.24	1.16	.71
25	3.71	2.33	1.18	.74
26	3.78	2.42	1.20	.77
27	3.85	2.50	1.23	.80
28	3.92	2.59	1.25	.82
29	3.99	2.67	1.27	.85
30	4.06	2.76	1.29	.88
31	4.13	2.85	1.31	.91
32	4.20	2.93	1.34	.93
33	4.27	3.01	1.36	.96
34	4.33	3.09	1.38	.99
35	4.39	3.16	1.39	1.01
36	4.45	3.23	1.41	1.03
37—40	4.20		1.34	
41—45	4.63		1.48	
46—51	5.06		1.61	
52—60	5.74		1.83	
61—70	6.52		2.07	
71—90	7.72		2.46	
91—120	9.78		3.11	
121—180	13.88		4.26	
181—360	21.62		6.88	

The curves of the internal tooth and of its pinion may best be drawn in by points, for the odontographic corrected tooth

GRANT'S ODONTOGRAPH

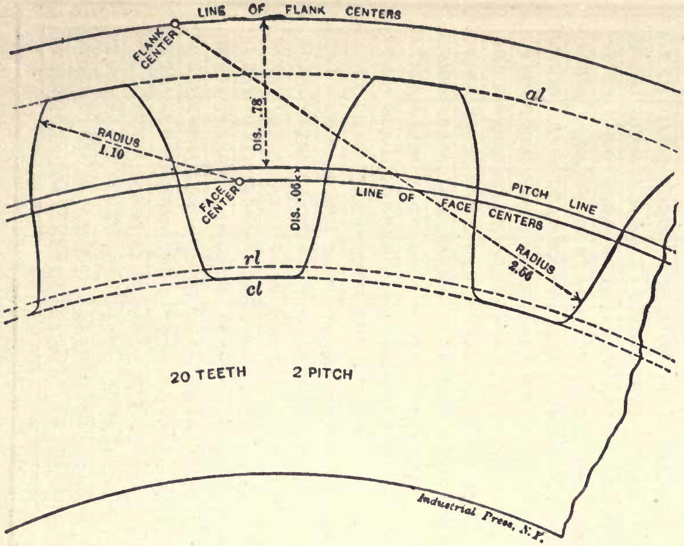


Fig. 1. Cycloidal Teeth.

Table for Cycloidal Teeth.

Number of Teeth in the Gear.		For One Diametral Pitch. For any other pitch divide by that pitch.				For One Inch Circular Pitch. For any other pitch multiply by that pitch.			
		Faces.		Flanks.		Faces.		Flanks.	
Exact.	Intervals	Rad.	Dis.	Rad.	Dis.	Rad.	Dis.	Rad.	Dis.
10	10	1.99	.02	— 8.00	4.00	.62	.01	—2.55	1.27
11	11	2.00	.04	—11.05	6.50	.63	.01	—3.34	2.07
12	12	2.01	.06	∞	∞	.64	.02	∞	∞
13½	13—14	2.04	.07	15.10	9.43	.65	.02	4.80	3.00
15½	15—16	2.10	.09	7.86	3.46	.67	.03	2.50	1.10
17½	17—18	2.14	.11	6.13	2.20	.68	.04	1.95	.70
20	19—21	2.20	.13	5.12	1.57	.70	.04	1.63	.50
23	22—24	2.26	.15	4.50	1.13	.72	.05	1.43	.36
27	25—29	2.33	.16	4.10	.96	.74	.05	1.30	.29
33	30—36	2.40	.19	3.80	.72	.76	.06	1.20	.23
42	37—48	2.48	.22	3.52	.63	.79	.07	1.12	.20
58	49—72	2.60	.25	3.33	.54	.83	.08	1.06	.17
97	73—144	2.83	.28	3.14	.44	.90	.09	1.00	.14
290	145—300	2.92	.31	3.00	.38	.93	.10	.95	.12
∞	Rack	2.96	.34	2.96	.34	.94	.11	.94	.11

CYCLOIDAL SYSTEM.

The three-point odontograph devised and calculated by Geo. B. Grant is one of the best methods for laying out accurate gear teeth or the templates for gear teeth. The odontograph gives the centers and radii for drawing circular arcs which approximate the actual tooth curves.

To apply the odontograph to any particular case of cycloidal teeth, first draw the pitch, addendum, root and clearance circles or lines, and space the pitch line for the teeth in the usual way.

Then draw the line of flank centers at the tabular distance, "dis" outside of the pitch line, and the line of face centers at the distance, "dis" inside of it. Take the face radius "rad" on the dividers, and draw in all the face curves from centers on the line of face centers; then take the flank radius "rad" and draw all the flank curves from centers on the line of flank centers.

The table gives the distances and radii if the pitch is either exactly one diametral or one inch circular, and for any other pitch multiply or divide as directed in the table. Fig. 1 shows the process applied to a practical case with the distances given in the figures. The odontograph may also be applied to laying out teeth for internal gears.

INVOLUTE SYSTEM.

To draft the tooth, lay off the pitch, addendum, root and clearance lines, and space the pitch line for the teeth, as in Fig. 2.

Draw the base line one-sixtieth of the pitch diameter inside the pitch line.

Take the tabular face radius on the dividers, after multiplying or dividing it as required by the table, and draw in all the faces from the pitch line to the addendum line from centers on the base line.

Set the dividers to the tabular flank radius, and draw in all the flanks from the pitch line to the base line.

Draw straight radial flanks from the base line to the root line, and round them into the clearance line.

Special Rule for the Involute Rack.

Draw the sides of the rack tooth as straight lines inclined to the line of centers $c\,O\,c$ at an angle of fifteen degrees, best found by quartering the angle of sixty degrees.

GRANT'S ODONTOGRAPH

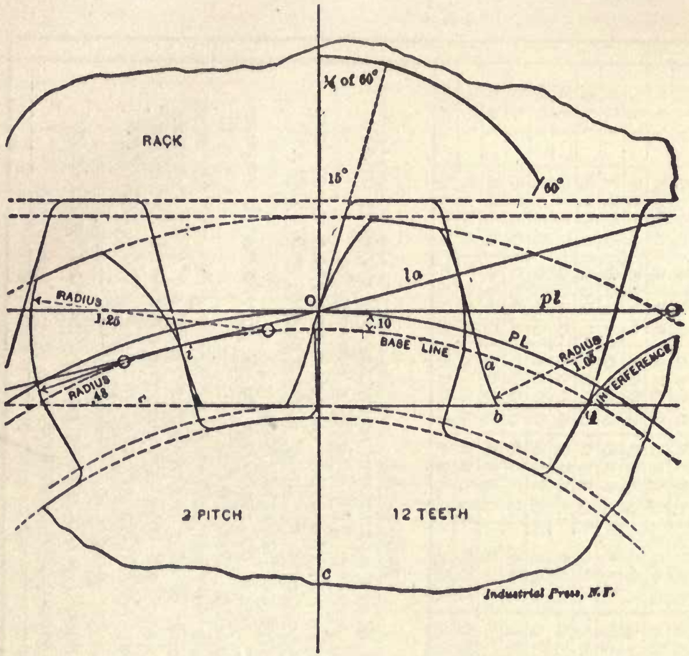


Fig. 2. Involute Teeth.

Draw the outer half $a\,b$ of the face, one-quarter of the whole length of the tooth, from a center on the pitch line, and with a radius of

2.10 inches divided by the diametral pitch.
.67 inches multiplied by the circular pitch.

Drafting Internal Involute Gears.

When the internal gear is to be drawn, the odontograph should be used as if the gear was an ordinary external gear; but care must be taken that the tooth of the gear is cut off to avoid interference. The point of the tooth may be left off altogether or rounded over to get the appearance of a long tooth.

The pinion tooth need not be carried in to the usual root line, but, as in the figure, may just clear the truncated tooth

Table for Involute Teeth.

TEETH.	Divide by the Diametral Pitch.		Multiply by the Circular Pitch.	
	Face Radius.	Flank Radius.	Face Radius.	Flank Radius.
10	2.28	.69	.73	.22
11	2.40	.83	.76	.27
12	2.51	.96	.80	.31
13	2.62	1.09	.83	.34
14	2.72	1.22	.87	.39
15	2.82	1.34	.90	.43
16	2.92	1.46	.93	.47
17	3.02	1.58	.96	.50
18	3.12	1.69	.99	.54
19	3.22	1.79	1.03	.57
20	3.32	1.89	1.06	.60
21	3.41	1.98	1.09	.63
22	3.49	2.06	1.11	.66
23	3.57	2.15	1.13	.69
24	3.64	2.24	1.16	.71
25	3.71	2.33	1.18	.74
26	3.78	2.42	1.20	.77
27	3.85	2.50	1.23	.80
28	3.92	2.59	1.25	.82
29	3.99	2.67	1.27	.85
30	4.06	2.76	1.29	.88
31	4.13	2.85	1.31	.91
32	4.20	2.93	1.34	.93
33	4.27	3.01	1.36	.96
34	4.33	3.09	1.38	.99
35	4.39	3.16	1.39	1.01
36	4.45	3.23	1.41	1.03
37—40	4.20		1.34	
41—45	4.63		1.48	
46—51	5.06		1.61	
52—60	5.74		1.83	
61—70	6.52		2.07	
71—90	7.72		2.46	
91—120	9.78		3.11	
121—180	13.38		4.26	
181—360	21.62		6.88	

The curves of the internal tooth and of its pinion may best be drawn in by points, for the odontographic corrected tooth is not as well adapted to the place as the true tooth, and no correction for interference is needed on the points of the

ball bearings. On pages 10 and 11 are given formulas and tables for determining the dimensions of the enveloping and enveloped cylinder in ball bearings, when the diameter of the ball and the number of balls are known. This table is, of course, equally applicable to roller bearings, when the diameter of the roller and the number of rollers are known. The formulas required for determining the dimensions are given at the head of the table on page 10, and in the body of the tables are given the values of the constants entering in these formulas for number of balls varying from 5 to 40.

On pages 12 to 15, inclusive, are given dimensions for two-point ball bearings. The table in the lower part of page 12 gives the dimensions relating specifically to the shape of the races when the diameter of the ball is known, while the dimensions in the tables on pages 13, 14 and 15 give the diameters of the ball races as determined from the number and diameter of the balls.

Assume as an example that it is required to find the dimensions of a two-point ball bearing having 20 balls of 3/8 inch diameter. From the table on page 12 we find:

Radius of race $R = 0.240$ inch,
Dimension $A = 0.053$ inch,
Dimension $B = 0.047$ inch,
Dimension $C = 0.023$ inch,
Dimension $S = 0.386$ inch,
Clearance $(S—D) = 0.011$ inch.

From the table on page 13 we find that for 20 balls of 3/8 inch diameter, diameter X, or the diameter of the inner ball race, equals 2.031 inches; diameter Y, or the diameter through the center of the balls, equals 2.416 inches, and diameter Z, or the diameter of the outer ball race, equals 2.802 inches. [Machinery, December, 1907, and January, 1908, Ball Bearings; May, 1909, Some Notes on Ball Bearings; Machinery's Reference Series No. 56, Ball Bearings.]

Shaft Couplings

The types of shaft couplings in general use vary greatly in appearance and construction. The method of construction is often dependent upon the space allowed for the coupling. When the coupling must be limited to its diameter, the clamp coupling, a type of which is shown on page 16, is especially suitable. When there are no limitations on the diameter of the coupling, plate or flange couplings, as shown on pages 17 and 18, are often used. Another simple form of coupling is shown on page 19. This coupling consists of a sleeve or muff, split on one side, which is placed over the shafts and their key; the outside of this sleeve is tapered at both ends, and it is clamped upon the shafts by means of two taper rings firmly held together by bolts. The crab coupling shown on page 20, dimensions for which are tabulated on page 21, should be classified as a clutch rather than as a coupling, a clutch, in general, being understood to mean a coupling which can be disengaged at will. Dimensions for the various classes of couplings are given beneath the illustrations referred to.

Clutches

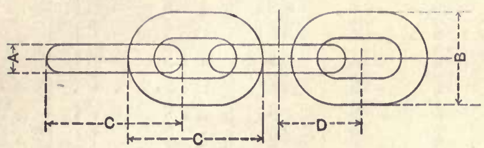
Clutches, as already mentioned, may be defined as disengaging couplings. Clutches may be divided, in general, into two classes, toothed clutches and friction clutches. The crab coupling, shown on page 20 and already referred to in the previous section, is an example of a toothed clutch. In this clutch one part, that to the left, is fastened to its shaft laterally, as well as keyed to the shaft to prevent turning. The part to the right is free to slide back and forth upon its shaft, but is, of course, also prevented from turning on the shaft by a key. The sliding motion for engaging or disengaging the clutch is accomplished by a forked lever

(Continued on page 33.)

CRANE CHAIN AND EYE BOLTS

CRANE CHAIN.

(United States Navy Standard.)

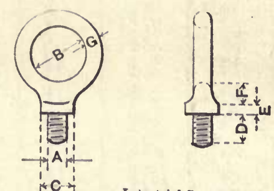


Industrial Press, N.Y.

A	B	C	D	Lbs. per Foot.	Load in Pounds. Ultimate.	Load in Pounds. Working.
1/4"	7/8"	1 5/16"	25/32"	.875	3360	670
5/16"	1 1/16"	1 1/2"	27/32"	1.000	5040	1000
3/8"	1 1/4"	1 3/4"	31/32"	1.70	7280	1460
7/16"	1 3/8"	2 1/16"	1 5/32"	2.00	10080	2020
1/2"	1 11/16"	2 3/8"	1 11/32"	2.50	13440	2690
9/16"	1 7/8"	2 5/8"	1 15/32"	3.20	16800	3360
5/8"	2 1/16"	3"	1 23/32"	4.125	20720	4140
11/16"	2 1/4"	3 1/4"	1 27/32"	5.00	25200	5040
3/4"	2 1/2"	3 1/2"	1 31/32"	5.875	30240	6050
13/16"	2 11/16"	3 3/4"	2 3/32"	6.70	35280	7060
7/8"	2 7/8"	4"	2 7/32"	8.00	40880	8180
15/16"	3 1/16"	4 3/8"	2 15/32"	9.00	47040	9410
1"	3 1/4"	4 5/8"	2 19/32"	10.70	53760	10750
1 1/16"	3 9/16"	4 7/8"	2 23/32"	11.20	60480	12100
1 1/8"	3 3/4"	5 1/8"	2 27/32"	12.50	68320	13660
1 3/16"	3 7/8"	5 9/16"	3 5/32"	13.70	76160	15230
1 1/4"	4 1/8"	5 3/4"	3 7/32"	16.00	84000	17000
1 5/16"	4 3/8"	6 1/8"	3 15/32"	16.50	91840	18400
1 3/8"	4 9/16"	6 3/8"	3 5/8"	18.40	101360	20300
1 7/16"	4 3/4"	6 11/16"	3 25/32"	19.70	109760	21900
1 1/2"	5"	7"	3 31/32"	21.70	120960	24200

TABLE FOR EYE BOLTS.

(Contributed by H. A. H)



Industrial Press, N.Y.

A	B	C	D	E	F	G	Number of Threads per Inch.	Strength at Bottom of Thread S = 10,000 Pounds.	Strength of Unstudded Chain Made from G Size Bar.
.375	2.	.75	.625	.1875	.375	.25	16	677	750
.5	2.125	1.	.75	.25	.5	.3125	13	1257	1172
.625	2.25	1.25	1.	.3125	.625	.4375	11	2018	2296
.75	2.375	1.4375	1.125	.3125	.6875	.5	10	3020	3000
.875	2.5	1.6875	1.375	.375	.75	.625	9	4194	4687
1.	2.75	1.875	1.5	.4875	.875	.75	8	5509	6750
1.125	2.875	2.125	1.625	.5	1.	.8125	7	6931	7921
1.25	3.	2.375	1.75	.5	1.125	.875	7	8899	9188
1.375	3.125	2.625	1.875	.5625	1.1875	1.	6	10541	12000
1.5	3.25	2.75	2.	.625	1.25	1.0625	6	12938	13546
1.625	3.375	3.	2.125	.6825	1.375	1.125	5.5	15149	15187
1.75	3.5	3.25	2.25	.75	1.5	1.25	5	17441	18750
1.875	3.625	3.5	2.375	.8125	1.625	1.3125	5	20490	20671
2.	3.75	3.75	2.5	.875	1.75	1.375	4.5	23001	22686

SETTING ANGLES FOR MILLING END MILLS

TABLE OF ANGLES FOR HEADSTOCK OF MILLING MACHINE WHEN CUTTING END TEETH IN MILLS, ETC.

No. of Teeth Cut.	Angle of Cutter with which the Teeth are Cut.									
	45°		50°		60°		70°		80°	
5	....	....	....	....	....	....	....	....	57°	8′
6	....	....	....	....	....	....	50°	55′	72	13
7	....	....	....	....	43°	36′	62	50	77	13
8	....	....	32°	57′	54	44	68	39	79	51
9	32°	58′	45	15	61	1	72	13	81	29
10	43	24	52	26	65	12	74	40	82	38
11	50	0	57	22	68	13	76	28	83	29
12	54	44	61	2	70	32	77	52	84	9
13	58	20	63	52	72	21	78	59	84	41
14	61	12	66	10	73	51	79	54	85	8
15	63	34	68	4	75	6	80	40	85	30
16	65	32	69	40	76	10	81	20	85	49
17	67	12	71	1	77	4	81	53	86	5
18	68	39	72	13	77	52	82	23	86	19
19	69	55	73	15	78	34	82	49	86	32
20	71	3	74	11	79	11	83	13	86	43
21	72	2	74	59	79	44	83	33	86	53
22	72	55	75	44	80	14	83	52	87	2
23	73	44	76	24	80	42	84	9	87	10
24	74	28	77	0	81	6	84	24	87	18
25	75	7	77	33	81	28	84	38	87	24
26	75	44	78	4	81	49	84	51	87	30
27	76	17	78	32	82	8	85	3	87	36
28	76	49	78	58	82	26	85	14	87	42
29	77	17	79	21	82	42	85	24	87	46
30	77	44	79	43	82	57	85	34	87	51
32	78	32	80	23	83	24	85	51	87	59
34	79	14	80	59	83	48	86	6	88	7
36	79	51	81	29	84	9	86	19	88	13
38	80	24	81	58	84	29	86	31	88	19
40	80	53	82	22	84	45	86	42	88	24
42	81	20	82	44	85	0	86	51	88	29
44	81	44	83	4	85	14	87	0	..	..
46	82	7	83	23	85	27	87	8	88	37
48	82	26	83	39	85	38	87	16	..	..
50	82	45	83	55	85	49	87	22	88	43
52	83	3	84	9	85	59	87	28	..	..
54	83	17	84	22	86	8	87	34	88	49
56	83	31	84	34	86	16	87	39	..	..
58	83	46	84	46	86	24	87	44	..	..
60	83	58	84	57	86	31	87	49	88	56

SETTING ANGLES FOR MILLING ANGULAR CUTTERS—I

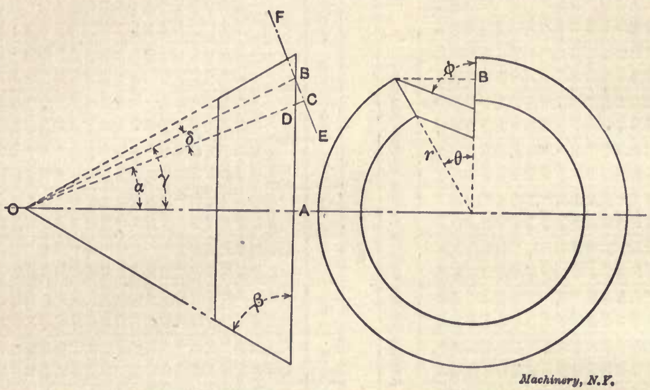


Fig. 1. Diagram for Calculating Setting-angle for Angular Cutters.

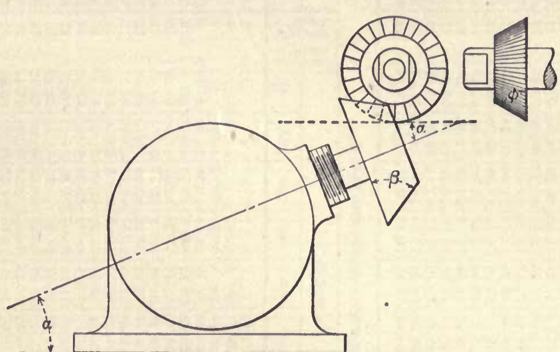


Fig. 2. Diagram of Head, Blank, and Cutter for Milling Teeth.

Let r = radius of blank,
n = the number of teeth,
β = the angle of blank,
ϕ = angle of cutter,

θ = tooth angle $= \frac{360}{n}$,

γ and δ angles, as shown in

In Fig. 1, the line OA is the axis of a cone which would result from prolonging the blank down to a point. The line OC is the intersection of the two planes which form the sides of the tooth space, and hence the cutter must run parallel to this line while cutting a space. The head must then be elevated so that the line OC is parallel with the table, and in doing so we will have turned it through an angle equal to AOC, or α. Line EF is drawn perpendicular to OC. From the figure,

$$\tan \gamma = \frac{AB}{AO}; \text{ but } AB = r \cos \theta; \text{ and } AO = r \tan \beta.$$

$$\text{Therefore } \tan \gamma = \frac{\cos \theta}{\tan \beta} \qquad (1)$$

$$\text{Also } \sin \delta = \frac{BC}{OB}; \text{ but } BC = r \sin \theta \cot \phi; \text{ and } OB = \frac{r \cos \theta}{\sin \gamma}.$$

$$\text{Therefore } \sin \delta = \frac{r \sin \theta \cot \phi}{\dfrac{r \cos \theta}{\sin \gamma}}$$

$$\text{or } \sin \delta = \tan \theta \cot \phi \sin \gamma. \qquad (2)$$

With equations (1) and (2) we can find the value of γ and δ, and their difference is the angle of elevation.

For $\beta = 0$ (case of an end mill, teeth on the end) equation (1) becomes $\tan \gamma = \frac{\cos \theta}{0}$, or $\tan \gamma$ is infinite, from which $\gamma = 90°$. Substituting sin 90 for $\sin \gamma$ in (2) gives $\sin \delta = \tan \theta \cot \phi$. But $\alpha = \gamma - \delta = 90 - \delta$, or $\cos \alpha = \cos (90 - \delta) = \sin \delta$, and since $\sin \delta = \tan \theta \cot \phi$ we have, finally, for the end mill

The designing of springs, when using these tables, becomes simply a matter of multiplying the load the spring is to carry by a proper factor of safety, and then selecting a resultant pressure in the tables; from this, the diameter of the wire and the deflection can be found readily. Dividing the deflection given in the table by the same factor of safety as was used for the load, will give the actual deflection per coil, and adding this value to the diameter of the wire will give the pitch for a compression spring. The number of coils will depend upon the amount of movement the spring requires, and knowing this, we divide the length of movement by the deflection per coil, which gives the number of effective coils, and then add 1½ coils for the ends. As a rule, the mean diameter of a helical spring should be from 8 to 10 times the diameter of the wire.

Helical Spring Tables

On pages 12 to 19 inclusive are given another set of helical spring tables arranged in a somewhat different manner from those already referred to. These tables are based upon a maximum stress of 80,000 pounds per square inch. When the outside diameter of the spring, in inches, and the diameter of wire are known, the values found from the tables are the load in pounds when the spring is down solid, and the free height of the spring in inches.

As an example, assume that the free height of a spring of 6 inches solid height, made of 1/8-inch steel and having 1 inch outside diameter is required. In the table headed "Diameter of Steel 1/8-inch," locate the outside diameter $D = 1$ inch, and opposite 1 inch and in the column headed 6 (solid height of spring), we find that the free height equals 11.88 inches. In the third column from the left we find that the maximum load the spring can carry is 70 pounds. [MACHINERY, January, 1910, Railway Edition, The Design of Heavy Helical Springs for Railroad Cars; MACHINERY'S Reference Series No. 58, Helical and Elliptic Springs, Chapter II, The Design of Heavy Helical Springs.]

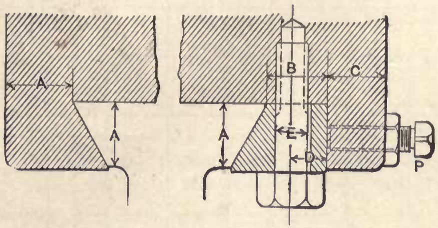
Elliptical Spring Tables

On pages 20 to 23 is given a set of tables for the calculation of elliptical springs. These tables give the maximum static load and the deflection under this load for a fiber stress of 80,000 pounds per square inch; L is the span or length of the spring in inches, F is the deflection of the spring under the load P in inches, given both for the semi- and full-elliptical springs; the values in the columns headed 1, 2, 3, etc., are the maximum static loads in pounds for various values of the product of the number of leaves in a semi-elliptical spring (or one-half the number of total leaves in a full-elliptical spring) multiplied by the width of the leaves in inches.

As an example assume that it is required to find the load to which a semi-elliptical spring made of six 1/16-inch leaves of a length of 10 inches and a width of ½ inch should be subjected. First multiply the number of leaves by the width of the leaves in inches: $6 \times 1/2 = 3$. Now locate in the table headed "Thickness of Steel, 1/16 inch," the length of the spring in the left-hand column. Then opposite the length of the spring, in this case 10 inches, and in the column headed 3, we find that the maximum static load to which this semi-elliptical spring may be subjected, is 62.4 pounds. In the second column from the left we find that the maximum deflection of the spring under load P equals 0.98 inch. [MACHINERY, January, 1910, The Design of Automobile Springs; MACHINERY'S Reference Series No. 58, Helical and Elliptic Springs, Chapter III, The Design of Elliptic Springs.]

MACHINE V-STRIPS AND STANDARD BRASS FLANGES

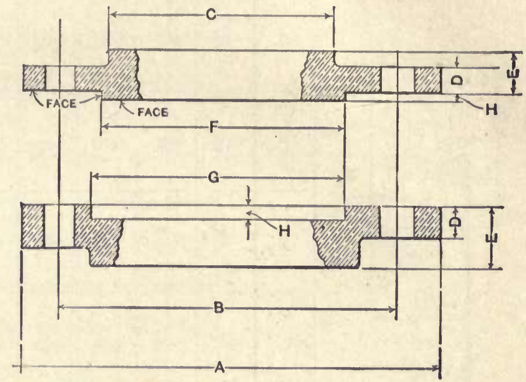
MACHINE V-STRIPS.



Computed by A. E. Ingham, Altrincham, Eng.

A	B	C	D	E	P
$\frac{1}{4}$	$\frac{5}{16}$	$\frac{1}{4}$	$\frac{3}{16}$	$\frac{3}{16}$	$\frac{1}{8}$
$\frac{3}{8}$	$\frac{7}{16}$	$\frac{5}{16}$	$\frac{9}{32}$	$\frac{1}{4}$	$\frac{3}{16}$
$\frac{1}{2}$	$\frac{9}{16}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{5}{16}$	$\frac{1}{4}$
$\frac{5}{8}$	$\frac{5}{8}$	$\frac{7}{16}$	$\frac{7}{16}$	$\frac{5}{16}$	$\frac{1}{4}$
$\frac{3}{4}$	$\frac{3}{4}$	$\frac{9}{16}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{5}{16}$
$\frac{7}{8}$	$\frac{7}{8}$	$\frac{11}{16}$	$\frac{9}{16}$	$\frac{1}{2}$	$\frac{5}{16}$
1	1	$\frac{3}{4}$	$\frac{5}{8}$	$\frac{1}{2}$	$\frac{3}{8}$
$1\frac{1}{4}$	$1\frac{1}{8}$	1	$\frac{3}{4}$	$\frac{5}{8}$	$\frac{3}{8}$
$1\frac{1}{2}$	$1\frac{3}{8}$	$1\frac{1}{8}$	$\frac{7}{8}$	$\frac{3}{4}$	$\frac{1}{2}$
$1\frac{3}{4}$	$1\frac{1}{2}$	$1\frac{1}{4}$	1	$\frac{3}{4}$	$\frac{5}{8}$
2	$1\frac{3}{4}$	$1\frac{1}{2}$	$1\frac{1}{8}$	$\frac{7}{8}$	$\frac{3}{4}$
$2\frac{1}{4}$	2	$1\frac{5}{8}$	$1\frac{3}{8}$	$\frac{7}{8}$	$\frac{3}{4}$
$2\frac{1}{2}$	$2\frac{1}{8}$	$1\frac{3}{4}$	$1\frac{1}{2}$	1	$\frac{3}{4}$
3	$2\frac{1}{2}$	2	$1\frac{7}{8}$	1	$\frac{7}{8}$

STANDARD MALE AND FEMALE BRASS FLANGES FOR 250 POUNDS PRESSURE.



Computed by A. de Bretteville, San Francisco, Cal.

Size of Pipe.	A	B	C	D	E	F	G	H	No. of Bolts.	Size of Bolts.
1	4	$2\frac{7}{8}$	$1\frac{3}{4}$	$\frac{1}{2}$	$\frac{9}{16}$	2	$2\frac{1}{32}$	$\frac{1}{8}$	4	$\frac{1}{2}$
$1\frac{1}{4}$	$4\frac{1}{2}$	$3\frac{1}{4}$	$2\frac{1}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$2\frac{1}{4}$	$2\frac{9}{32}$	$\frac{1}{8}$	4	$\frac{1}{2}$
$1\frac{1}{2}$	5	$3\frac{5}{8}$	$2\frac{1}{4}$	$\frac{1}{2}$	$\frac{3}{4}$	$2\frac{5}{8}$	$2\frac{21}{32}$	$\frac{1}{8}$	4	$\frac{5}{8}$
2	6	$4\frac{1}{2}$	$2\frac{7}{8}$	$\frac{1}{2}$	$\frac{7}{8}$	$3\frac{1}{4}$	$3\frac{9}{32}$	$\frac{1}{8}$	5	$\frac{5}{8}$
$2\frac{1}{2}$	7	$5\frac{1}{2}$	$3\frac{5}{8}$	$\frac{9}{16}$	1	4	$4\frac{1}{32}$	$\frac{1}{8}$	6	$\frac{5}{8}$
3	$7\frac{1}{2}$	6	$4\frac{1}{4}$	$\frac{5}{8}$	$1\frac{1}{8}$	$4\frac{1}{2}$	$4\frac{17}{32}$	$\frac{1}{8}$	6	$\frac{5}{8}$
$3\frac{1}{2}$	$8\frac{1}{2}$	$6\frac{3}{4}$	$4\frac{7}{8}$	$\frac{11}{16}$	$1\frac{1}{8}$	$5\frac{1}{4}$	$5\frac{9}{32}$	$\frac{1}{8}$	6	$\frac{3}{4}$
4	9	$7\frac{1}{4}$	$5\frac{3}{8}$	$\frac{11}{16}$	$1\frac{1}{4}$	$5\frac{3}{4}$	$5\frac{25}{32}$	$\frac{1}{8}$	6	$\frac{3}{4}$
$4\frac{1}{2}$	$9\frac{1}{2}$	$7\frac{3}{4}$	6	$\frac{11}{16}$	$1\frac{1}{4}$	$6\frac{1}{4}$	$6\frac{9}{32}$	$\frac{1}{8}$	8	$\frac{3}{4}$
5	10	$8\frac{1}{4}$	$6\frac{3}{8}$	$\frac{3}{4}$	$1\frac{3}{8}$	$6\frac{3}{4}$	$6\frac{25}{32}$	$\frac{1}{8}$	8	$\frac{3}{4}$
6	11	$9\frac{1}{4}$	$7\frac{1}{2}$	$\frac{3}{4}$	$1\frac{3}{8}$	$7\frac{3}{4}$	$7\frac{25}{32}$	$\frac{1}{8}$	8	$\frac{3}{4}$
7	$12\frac{1}{2}$	$10\frac{3}{4}$	9	$\frac{13}{16}$	$1\frac{3}{8}$	9	$9\frac{1}{32}$	$\frac{1}{8}$	8	$\frac{3}{4}$
8	$13\frac{1}{2}$	$11\frac{3}{4}$	10	$\frac{7}{8}$	$1\frac{5}{8}$	10	$10\frac{1}{32}$	$\frac{1}{8}$	8	$\frac{3}{4}$
9	15	$13\frac{1}{4}$	$11\frac{1}{4}$	$\frac{15}{16}$	$1\frac{5}{8}$	$11\frac{1}{4}$	$11\frac{9}{32}$	$\frac{1}{8}$	12	$\frac{3}{4}$
10	16	$14\frac{1}{4}$	$12\frac{1}{2}$	$\frac{15}{16}$	$1\frac{7}{8}$	$12\frac{1}{4}$	$12\frac{9}{32}$	$\frac{1}{8}$	12	$\frac{3}{4}$
12	19	17	$14\frac{3}{4}$	$1\frac{1}{16}$	$1\frac{7}{8}$	$14\frac{1}{2}$	$14\frac{17}{32}$	$\frac{1}{8}$	12	$\frac{3}{4}$